NAVORD REPORT 6664

DEVELOPMENT OF FLEXIBLE EXPLOSIVE LEAD, MK 11 MOD 0 AND WARHEAD BOOSTER, MK 36 MOD 1 (U)

30 JUNE 1959

U. S. NAVAL ORDNANCE LABORATORY

WHITE OAK, MARYLAND

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IDENTIFIERS: TALOS (U)

DEVELOPMENT OF FLEXIBLE EXPLOSIVE LEAD, MK 11 MOD 0 AND WARHEAD BOOSTER, MK 36 MOD 1 (U)

Prepared by:
B. J. Meleski

Approved by: ______________________
Chief, Explosion Dynamics Division

ABSTRACT: A thermally protected Flexible Explosive Lead, the Mk 11 Mod 0, and a thermally protected Warhead Booster, the Mk 36 Mod 1, have been developed for use in the TALOS 6b1(dc) missile (TALOS Missile Mk 11 Mod 2). These items replace the previously developed Flexible Explosive Lead, Mk 2 Mod 0, and the Warhead Booster, Mk 36 Mod 0. They will withstand the anticipated temperature excursions of the TALOS 6b1(dc) missile which the earlier designed items could not tolerate. The design of both of these items has been kept close enough to the Flexible Explosive Lead Mk 2 Mod 0, and the Warhead Booster, Mk 36 Mod 0, so that the functioning and reliability estimates previously determined should not be affected.

Explosions Research Department
U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, Maryland

NavOrd Report 6664 30 June 1959

This report discloses work connected with the development of a thermally insulated Flexible Lead, Mk 11 Mod 0, and an insulated Warhead Booster, Mk 36 Mod 1, for use with the TALOS missile. The work was performed under NOL Project 512-525/53019/40040, TALOS Warhead Development.

The information should be of interest to individuals working on the development and use of explosive components and fuze trains. It should be of special interest to those engaged in overcoming the design problems associated with the aero-dynamic heating of explosive components and fuzes.

MELL A. PETERSON
Captain, USN
Commander

C. J. Aronson

C. J. ARONSON
By direction

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DEVELOPMENT OF FLEXIBLE EXPLOSIVE LEAD, MK 11 MOD 0, AND WARHEAD BOOSTER, MK 36 MOD 1 (U)

INTRODUCTION

1. Missiles flying at high velocity are subject to aerodynamic heating. The aerodynamic heating of explosive ordnance often results in the exposure of explosive components of conventional design to temperatures which are beyond their safe and reliable upper temperature limits. Then, either deterioration or cook-off may ensue. The armed services are conducting and supporting investigations designed to extend the upper temperature capability of explosive components and fuze trains. For the most part these investigations have been concerned with a search for explosives and construction materials of greater temperature stability. However there occurs from time to time the need to meet immediately the high temperatures of a specific situation. This was the case with the TALOS 6b1(dc) missile, in which both the lead and booster had to withstand temperatures in excess of that which the RDX base explosive in them could withstand.

FLEXIBLE EXPLOSIVE LEAD, PRELIMINARY INVESTIGATION

2. The Bendix Aviation Corporation has made a thermal analysis[1] of the TALOS 6b1(sc) missile warhead area. The heating rates expected in the TALOS 6b1(dc) missile warhead area are about the same as those expected in the TALOS 6b1(sc) missile; however, the TALOS 6b1(dc) missile is to be in flight approximately 3 minutes longer than is the TALOS 6b1(sc) missile. Consequently it was determined that if the Flexible Explosive Lead Mk 2 Mod 0, shown in Figure 1, used in the TALOS 6b1(sc) missile were used in the TALOS 6b1(dc) TALOS missile, the explosive would be subjected to temperatures dangerously close to the cook-off point. The vinylite covered detonating cord, between two brass cups (see Figure 1) would be heated primarily by radiant energy. The outer vinylite surface could reach

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1 - Bendix Aviation Corporation Thermal Analysis AGM 1203 and AGM 1286.

approximately 427°F while the temperature on the explosive surface within the cord could reach about 398°F at the end of missile flight. Heat addition by convection would be very small. Conduction heating of the lead would also be small since no part of the lead would be in contact with a surface heated to above 309°F at the end of missile flight. Figure 2 shows mock-up of the flexible lead orientation with respect to the S and A mechanism and the booster in the TALOS 6bl(dc) missile.

3. Since the explosive in the detonating cord, between the ball cups, will reach temperatures at which explosive reaction can occur, the problem appeared to be one of insulating against radiant energy. It was decided to use the Flexible Explosive Lead, Mk 2 Mod 0, with the following modifications:

(a) Increase the overall lead length to 7 inches, and

(b) Place an insulating cover (a reflector of infra-red energy waves) over the detonating cord.

The length change was necessitated by the different geometry existing between the TALOS 6bl(sc) missile and the TALOS 6bl(dc) missile. Figure 1 also shows the modified insulated Flexible Explosive Lead, Mk 11 Mod 0.

4. In choosing an insulating covering a number of materials were checked for cost, thermal conductivity, emissivity, flexibility, tensile strength, and chemical stability up to 450°F. Of the materials checked, the one which seemed the best suited for this application was an aluminized Mylar having a 0.0005-inch thick Mylar base sputtered with a 0.00002-inch thick layer of aluminum. The Mylar protects against thermal conduction while the highly reflective aluminum provides protection from radiant energy. By using a multi-layer wrap of the aluminized Mylar, an effective insulation against both forms of heat energy is obtained.

5. The lead-to-booster detonation-transfer reliability, previously measured between the Flexible Explosive Lead, Mk 2 Mod 0, and the Warhead Booster, Mk 36 Mod 0, should not be affected by these changes as no change was made to the ball connectors through which detonation is transferred.

WRAPPING PROCEDURE

6. The procedure decided upon for using the Mylar film as insulation was to form a multilayer base wrapping (see Figure 3, Step 1) covered by a spiraled overwrap to keep the base wrap from gapping or unwinding (see Figure 3, Step 2) with Mylar strips wrapped over the ends of the previous layers to hold them in position (see Figure 3, Step 3). Pliobond adhesive was applied to each end of the wrappings between the plastic films. The length of the base wrapping was 9.575 inches and its width was 5.750 inches. The spiral wrap was 17.350 inches long and 1.0 inch in width. The end strips were 4.875 inches long and 0.140 inch wide. The Mylar film was wrapped over explosive leads with the Mylar face down, i.e. toward the explosive. The dimensions of the film were chosen on the basis of obtaining maximum insulating thickness consistent with lead flexibility and ease of handling.

FLEXIBLE LEAD HEATING AND EVALUATION TESTS

7. Figure 4 shows the oven used to test the thermal properties of the insulated flexible leads. The oven consists of #10 Nichrome wire wound to form a cylinder 1-3/4 inches inside diameter by 4-1/2 inches long. The ends of the wire were connected to a transformer which in turn was connected to a Variac so that the rate of heating could be controlled. Mylar wrapped flexible explosive leads were constructed with a thermocouple placed in contact with the explosive in each lead by insertion into a slit cut in the vinylite sheath of the detonating cord. Another thermocouple was placed on the outer surface of the wrapped leads at a point midway between the ends such that each lead would have both thermocouples in a plane normal to the cylindrical axis of the explosive. Prior to a heat test, the oven was housed in asbestos and the thermocouples were connected to temperature recorders.

8. Figure 5 shows the composite results of the heating tests on eight specially wrapped flexible explosive leads referred to above. The upper shaded area gives the bounds of the experimental temperatures imposed on the outer surface of the Mylar sheath. It should be noted that these temperatures are greater than those imposed by the heating of the missile in flight (see upper solid line). The lower shaded zone shows the observed temperature range at the explosive-vinylite interface as a function of time under the imposed

experimental heating conditions. The minimum time at which cook-off occurred even at the exaggerated heating rate was 6 minutes and 34 seconds. Missile flight time is 5 minutes and 50 seconds. For comparative purposes the temperature at the vinylite-explosive interface on an uninsulated lead under the forcing temperature shown by the upper solid line previously referred to is shown in the lower solid line. The solid lines as indicated were calculated by Bendix. These results indicate that the Mylar wrap is adequate to prevent cook-off during the flight of the missile and that the maximum explosive temperature at the end of the missile's flight will not exceed 360°F.

9. The remaining question of whether or not the lead would still be operable after reaching the 360°F temperature can be answered by the results of work[2] in which it was shown that the uninsulated Flexible Explosive Lead, Mk 2 Mod 0, after being heated to a temperature of 380°F, was operable both as to its ability to function from the S-and-A lead and as to its ability to initiate the warhead booster. Since the connector ends through which initiation and detonation transfer are effected were not changed, the insulated lead should perform its function without impairment by the heat cycle it would experience in the TALOS 6bl(dc) missile during actual flight.

10. As part of the evaluation program for release of components for Navy acceptance the uninsulated Flexible Explosive Lead, Mk 2 Mod 0, has been subjected to a complete series of environmental tests. This included:

- Jolt Test (Mil-Std-350)
- Jumble Test (Mil-Std-351)
- Impact Test
- Vibration Test (Aircraft, Room Temperature)
- Vibration Test (Aircraft, Low Temperature)
- Vibration Test (Missile, Room Temperature)
- Vibration Test (Missile, High Temperature)
- Temperature and Humidity Test (Mil-Std-354)
- Vacuum-Steam Pressure Test (Mil-Std-305)
- Waterproofness Test (Mil-Std-314)
- Tensile Test

The Flexible Explosive Lead, Mk 2 Mod 0, passed all of these tests successfully. Most of the results of the testing on the uninsulated Flexible Explosive Leads, Mk 2 Mod 0, are

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2 - NavOrd Report 4445: "Explosive Lead XF-1B" of 9 Apr 57 by W. M. Slie, M. H. Rowe, and R. H. Stresau

considered to be equally valid for the insulated leads. The following environmental tests were carried out to evaluate the changes produced by the addition of the insulation:

Vibration Test (Aircraft, Low Temperature)
Vibration Test (Aircraft, Room Temperature)
Vibration Test (Missile, Room Temperature)
Vibration Test (Missile, High Temperature)
Tensile Strength Test.

The insulated lead passed all of these tests successfully. The final arrangement of the new insulated lead which was designated Lead, Explosive, Flexible, Mk 11 Mod 0, is shown in Figure 6.

THE WARHEAD BOOSTER, PRELIMINARY INVESTIGATION

11. The Bendix thermal studies[1] further pointed out a possibility of cook-off of the Warhead Booster, Mk 36 Mod 0, (Figure 7) during flight. In this case the heat input is by contact between the booster can and the booster well which in turn derives its heat from the diffuser tube and the forward bulkhead shown in Figure 2. That part of the well with which the booster might make contact is at about 450°F at end of missile flight. The thermal analysis[1] predicted that the outer surface of explosive at this point will reach approximately 415°F — well beyond the cook-off point of the explosive. Another similar high temperature point due to conduction heating is the retainer end of the booster. In view of these thermal considerations, it was decided, in order to insulate the booster, to redesign:

(a) the end cup

(b) the retainer, and

(c) the compression spring to make it compatible with the new end cup.

It was decided to retain the other components of the Warhead Booster, Mk 36 Mod 0. Figure 7 shows the new booster, Warhead Booster, Mk 36 Mod 1.

THE BOOSTER REDESIGN

12. Possible materials which could be used in making the retainer and end cup were checked for cost, compatibility with explosive, thermal parameters, tensile strength, shear strength, coefficient of linear expansion, and chemical stability up to 500°F. The material which best met the desired requirements was Diall 52-20-30, a glass filled diallylphthalate plastic. It was decided to mold, rather than machine, the retainer and end cup because the molded parts would have a better finish and, in the quantities required, could be obtained quicker and cheaper.

13. The compression spring was redesigned because design changes in the cup would prevent the booster from being locked in the booster well and would prevent securing the spring to the end cup if the compression spring of the Warhead Booster, Mk 36 Mod 0, were used. Steel music wire ASTM A22851 was chosen for the spring because of its desirable mechanical properties. The spring was designed to provide two inactive coils on the end next to the end cup so that when the spring is potted into the end cup the potting compound will not flow over the inactive coils into the active coils and thus destroy some of the spring characteristics. The free end of the spring has one inactive coil. The spring has a total of six coils, three of which are active. The spring was so designed to insure that the booster will fit into the J-slots of the booster well and yet not over-stress the wire. The spring can be subjected to a force, before booster movement occurs, approximately 25 percent greater than the maximum force on the spring created by the acceleration of the missile. The force on the spring due to missile acceleration would tend to cause the booster to snap out of the booster well J-slots.

THE BOOSTER HEATING AND EVALUATION TESTS

14. A heating apparatus shown in Figure 8 was designed so that the booster could be heated at specific rates. The apparatus had two heating elements. One heating element consisted of #10 Nichrome wire cylindrically coiled to an inside diameter of 1-3/4 inches and a length of 4-1/2 inches. The second heating element consisted of #10 Nichrome wire cylindrically coiled to an inside diameter of 1-3/4 inches and 1 inch in length. Into this latter element was placed a cylindrical copper insert containing a thermocouple. Each element was connected to a separate transformer and each transformer was connected to a separate Variac. Thus each element could be heated independently.

15. Four redesigned (one inert loaded and three live loaded)boosters, without springs, were subjected to heating tests in the apparatus described. One thermocouple was placed on the outside of each booster at the midpoint between the end of the retainer and the end cup and another on the outside diameter of the explosive at the point where the explosive comes in contact with the bottom of the booster can. The loaded booster was placed into the heating apparatus such that the end cup fit tightly into the copper insert, see Figure 8. The apparatus and booster were then housed in an asbestos covering and the thermocouples connected to recorders. Different heating rates were attained in each test by adjusting the Variacs.

16. Figure 9 shows the results obtained on an inert loaded booster while Figures 10, 11, and 12 show the results obtained on live loaded boosters. Tests on the inert loaded booster indicated that the inert material simulating the explosive would not reach a temperature greater than 360°F in the neighborhood of the end cup at a time corresponding to the end of missile flight when the heating rate was very much in excess of that expected in the missile. This was also a severe test from the point of view of heat conductance since the entire surface of the end cup was tightly fitted into the copper insert heat source. The contact and conductance was greater than that which would be experienced on the missile. Tests at a somewhat lower rate, which was still in excess of that expected in flight, yielded a maximum temperature of less than 300°F for the inert load.

17. No attempt was made to determine the temperatures on the explosive at the retainer end because the temperatures expected there, as determined by Bendix, are less than at the end cup section, and the wall thickness of the retainer is greater than the wall thickness of the end cup. Thus the temperatures on the explosive at the retainer end would be less than the temperatures on the explosive at the end cup section.

18. Temperatures around the J-slot area of the booster well are less than at possible contact points of booster end cup and booster well. The contact area between booster pins and booster well is small. Also there is considerable mass of metal between explosive and pins. The temperatures on the explosive, due to conduction heating, would therefore be well below detrimental temperatures. There is no conduction

heating problem of the explosive through the compression spring because the contact area of the compression spring and booster well is small and there is 0.125 inch of plastic insulation between the spring and booster can, an amount far in excess of that required for adequate thermal protection.

19. Observations of the diallylphthalate plastic parts showed no visible deterioration after subjection to the temperatures somewhat in excess of 500°F obtained at the end of the heat cycle. The results of the live loaded booster tests indicate that under the most severe heating conditions in the redesigned booster, explosive will be at a temperature below 325°F at end of missile flight.

20. The booster in the TALOS 6b1(sc) and 6b1(dc) missiles initiate the warheads in the radial direction. Since no design changes were made in the effective peripheral area about which the warhead is initiated (all design changes being made at the booster ends) it was assumed that the warhead booster transfer efficiency to the warhead was unaffected by the design changes.

21. As part of the evaluation program for release of components for Navy acceptance the booster has been subjected to the following environmental tests:

Temperature and Humidity Test (Mil-Std-354)
Vacuum-Steam Pressure Test (Mil-Std-305)
Vibration Test (Aircraft, Room Temperature)
Jumble Test (Mil-Std-351)
Waterproofness Test (Mil-Std-314)

These tests apply directly to the redesigned booster. Additional environmental tests carried out on the Warhead Booster Mk 36 Mod 0 considered equally valid for the redesigned booster included:

Jolt Test (Mil-Std-350)
Jumble Test (Mil-Std-351)
Impact Test
Vibration Test (Missile, Room Temperature).

The redesigned booster passed these tests successfully. This booster, designated Booster, Warhead, Mk 36 Mod 1, is shown in Figure 13.

CONCLUSIONS

22. The Bendix thermal analysis of the TALOS 6bl(sc) missile was based on the most pessimistic trajectory of the missile. The experimental insulated leads were wrapped extremely tight with aluminized Mylar. As a result the heat transfer to the explosive is greater than can be expected with production wrapped leads for use in missiles. The experimental leads were subjected to greater heating rates than would be expected in the TALOS 6bl(dc) missile without detrimental effects. It can therefore be stated that the explosive in the Flexible Explosive Lead, Mk 11 Mod 0, when used in the TALOS 6bl(dc) missile will be well below 360°F and will neither cook-off nor be impaired in its explosive properties.

23. The anticipated heating will also not adversely affect the performance of the booster. In testing the heat resistance of the booster these items were subjected to experimental temperature excursions far greater than those expected in the TALOS 6bl(dc) missile and they were tested in an oven which offered much greater conductance of heat to the booster than would occur with the booster in the booster well on the missile. The test results indicated that the explosive temperature at the end of missile flight will be less than 325°F and the explosive in the Warhead Booster, Mk 36 Mod 1, will not cook-off or be impaired in its explosive characteristics.

24. These items pass standard environmental tests and have been recommended for release as part of the items associated with the Warhead Mk 9 Mod 0 , for the TALOS Missile Mk 11 Mod 2.[3] The flexible lead and the warhead booster are covered specifically by Bureau of Ordnance drawings:

LD 480230 - Explosive Lead, Flexible, Mk 11 Mod 0.

LD 480229 - Booster, Warhead, Mk 36 Mod 1.

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3 - NOL Secret Ltr to BuOrd X11/2, 00764 of 26 Nov 1958.

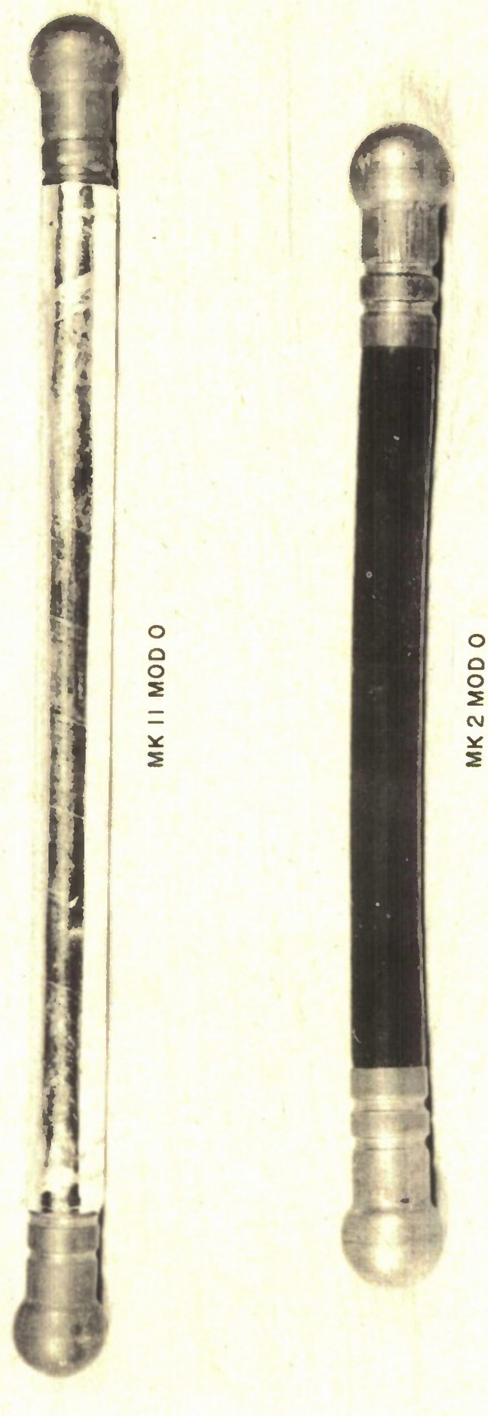


FIG. 1 FLEXIBLE EXPLOSIVE LEADS, MK 2 MOD 0, AND MK 11 MOD 0

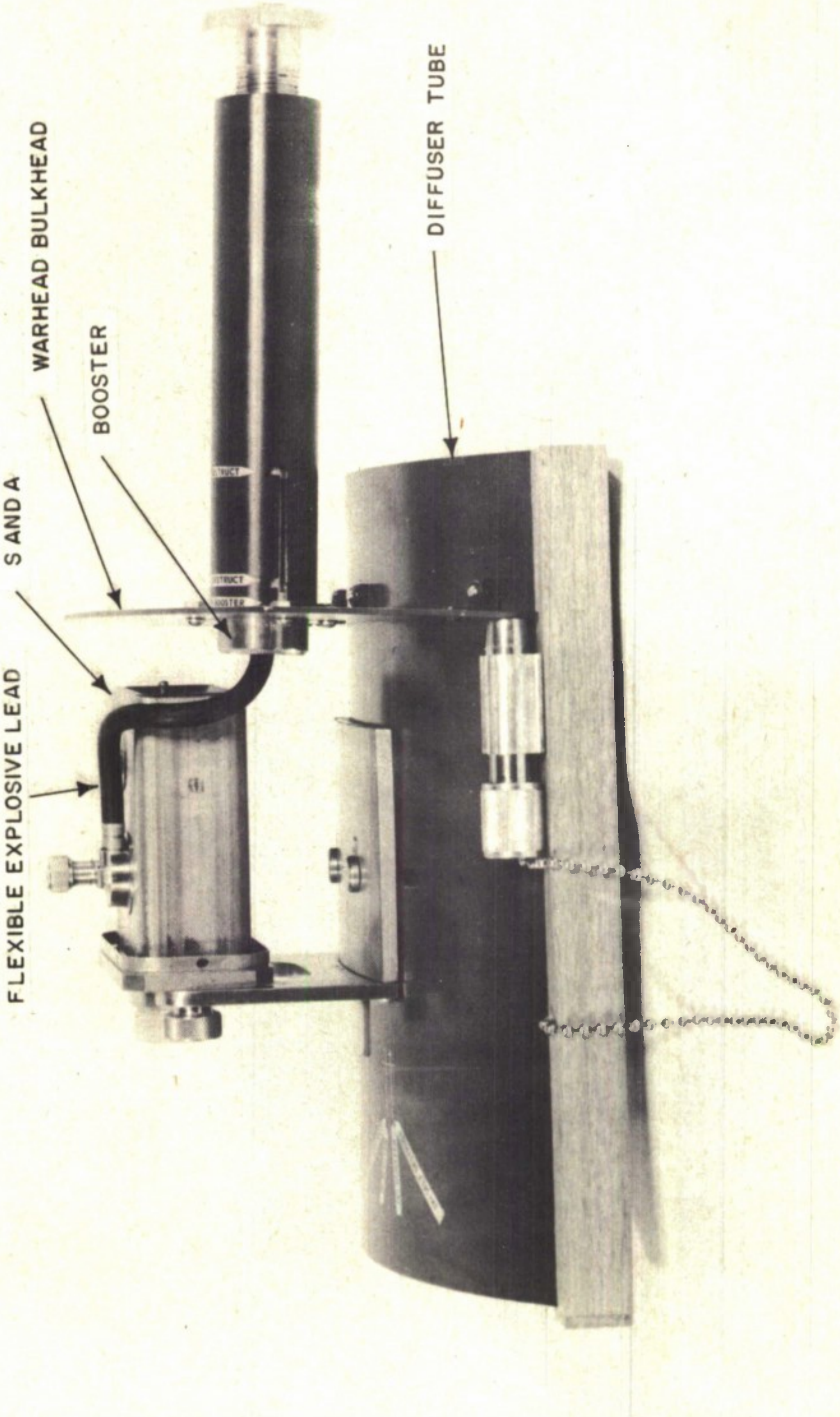


FIG. 2 MOCK-UP OF S AND A, BOOSTER, AND FLEXIBLE EXPLOSIVE LEAD AS USED IN "TALOS" 6BI (dc) MISSILE

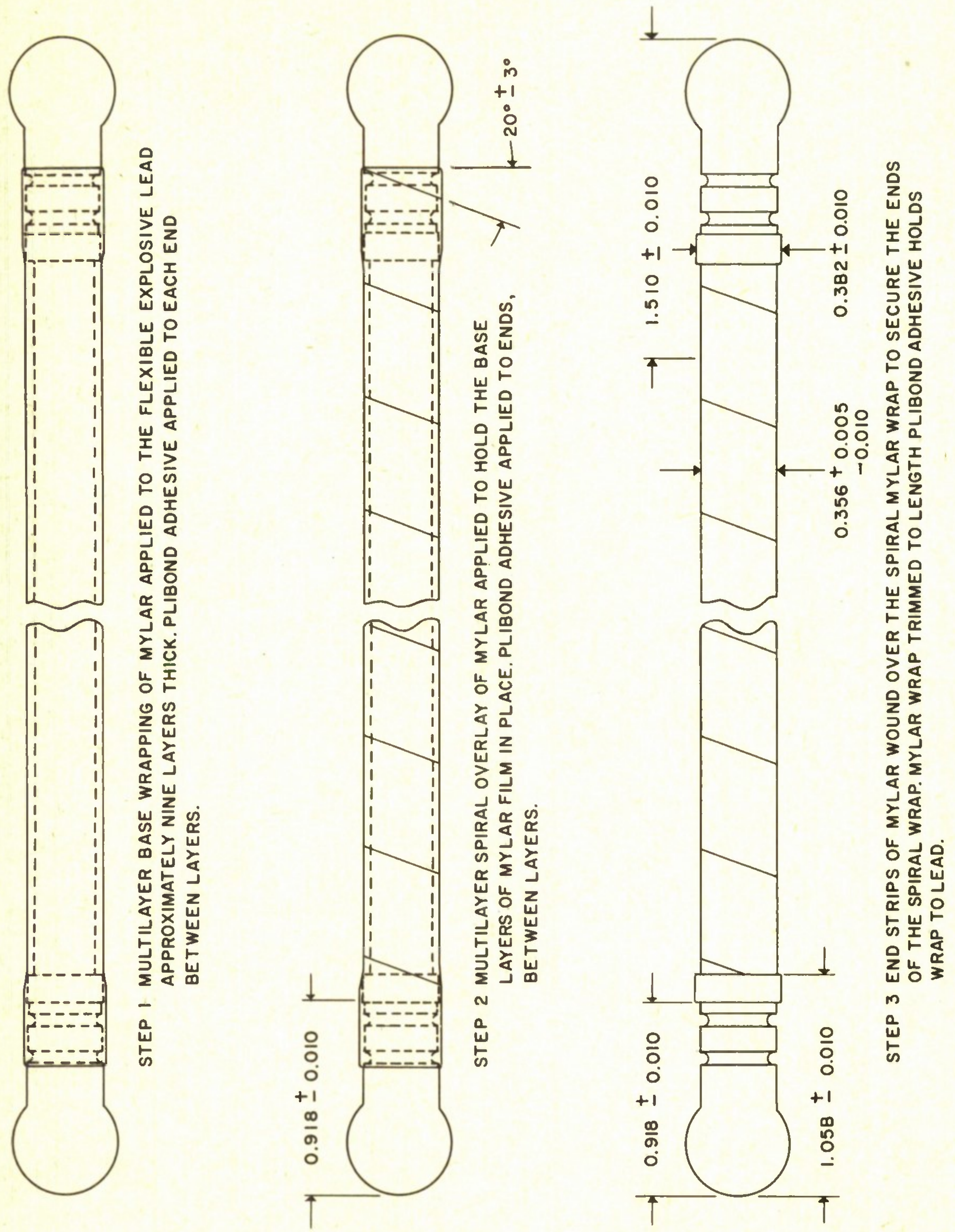


FIG. 3 FLEXIBLE EXPLOSIVE LEAD WRAPPING

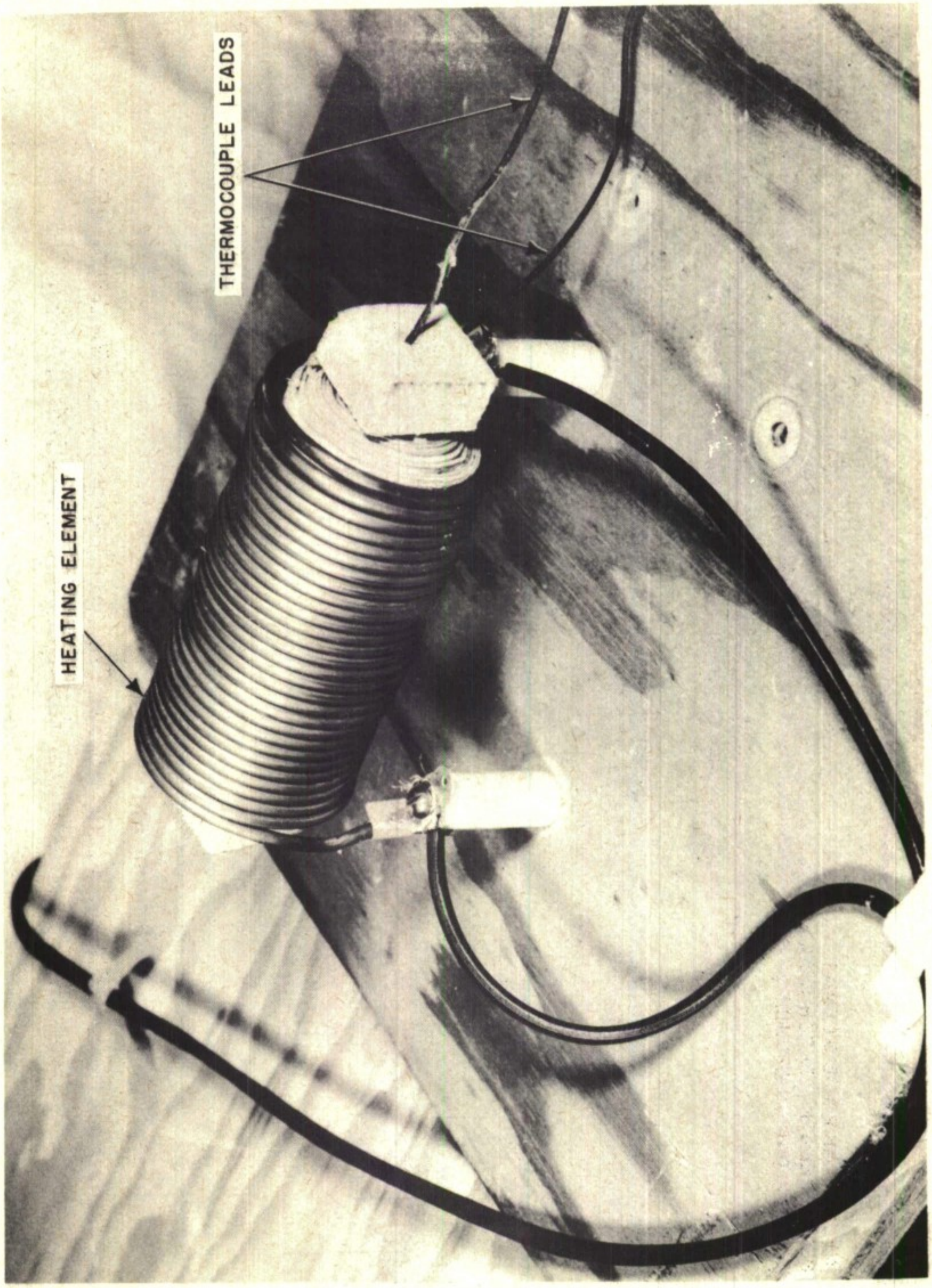


FIG. 4 HEATING ELEMENT TO TEST THERMAL CHARACTERISTICS OF FLEXIBLE EXPLOSIVE LEAD

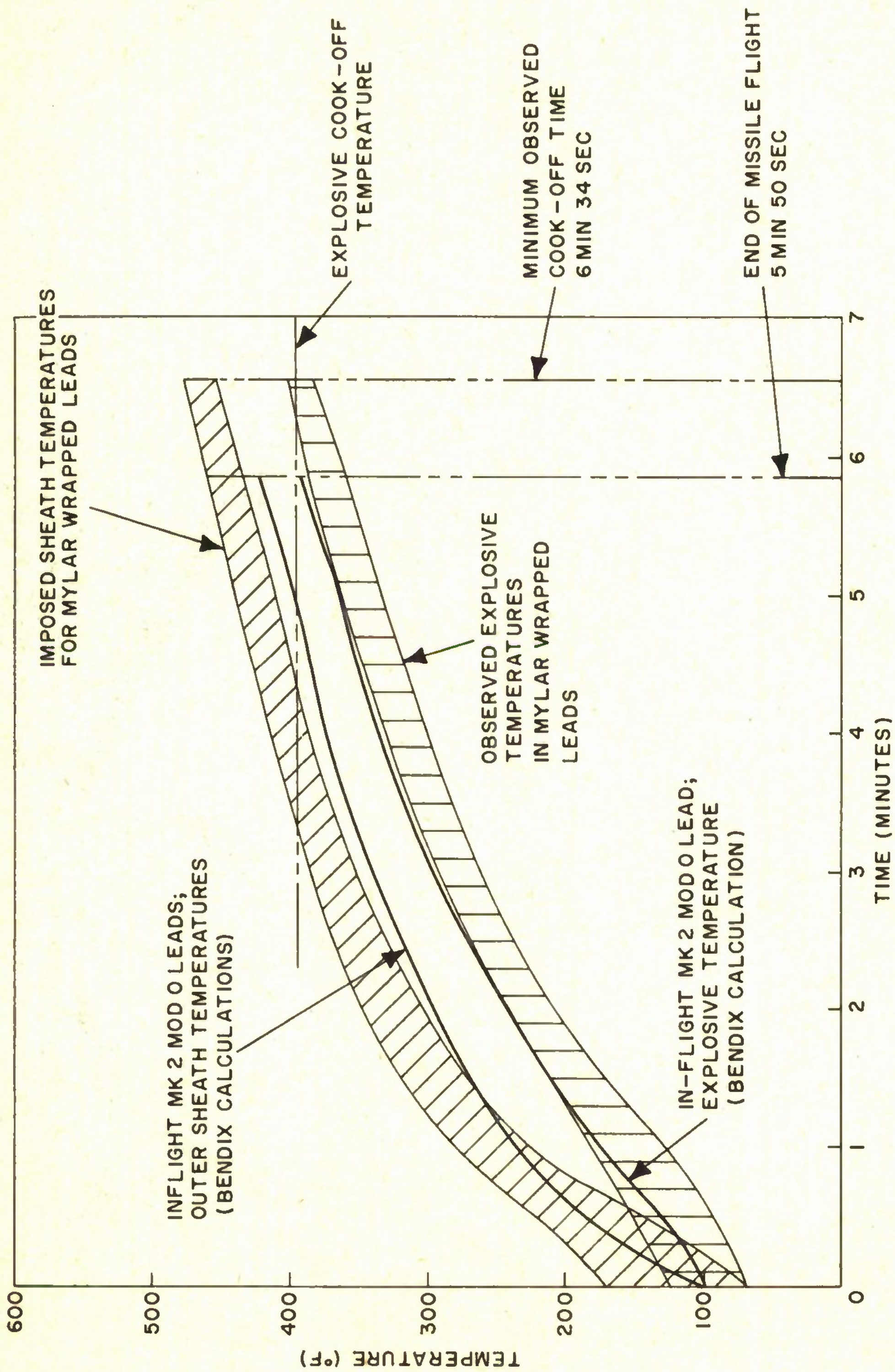
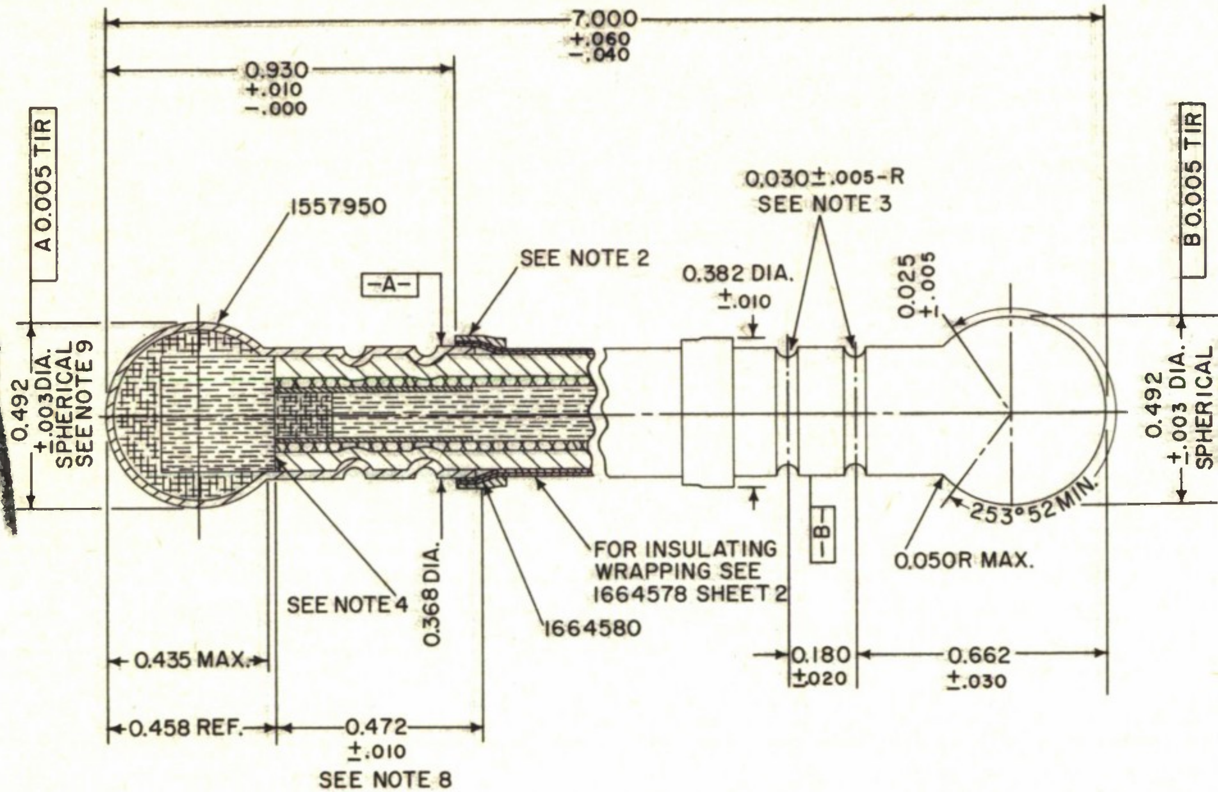


FIG.5 THERMAL TEST RESULTS ON EIGHT MYLAR-WRAPPED FLEXIBLE EXPLOSIVE LEADS (MK 2 MOD O TYPE)



NOTES: UNLESS OTHERWISE SPECIFIED:

1. FOR LIST OF DRAWINGS, PARTS AND SPECIFICATIONS SEE LD 480230.

2. APPLY ADHESIVE, RUBBER, MIL SPEC MIL-A-5092, TYPE 11 TO FORM BOND AND SEAL.
ADVISORY:
PRIOR TO ASSEMBLY, COAT THE VINYLITE COVERING OF CORD AND SLEEVE ASSEMBLY, 1664580 FOR A DISTANCE OF 0.500 + .100-.000 FROM ONE END WITH ADHESIVE, RUBBER, MIL SPEC MIL -A-5092, TYPE 11. LET DRY UNTIL TACKY AND THEN REPEAT. AFTER SECOND APPLICATION ASSEMBLE IMMEDIATELY AS SHOWN. ADHESIVE MUST BE WET AT TIME OF ASSEMBLY.
REPEAT THE ENTIRE OPERATION FOR THE OTHER END.

3. CRIMP 360°, BOTH ENDS, AS SHOWN.

4. CORD AND SLEEVE ASSEMBLY, 1664580, TO BE SEATED AGAINST THE EXPLOSIVE OF THE CUP AND PELLET ASSEMBLY, 1557950, ON BOTH ENDS.

5. INTERPRET ABBREVIATIONS IN ACCORDANCE WITH MIL-STD-12.

6. INTERPRET DIMENSIONS AND TOLERANCES IN ACCORDANCE WITH MIL-STD-8.

7. FOR DESCRIPTIONS AND REQUIREMENTS SEE OS 7296.

8. THE .368± .008 DIAMETER APPLIES AFTER CRIMPING FOR LENGTH SHOWN.

9. THE .492 ± .003 SPHERICAL DIA APPLIES FOR A MINIMUM ARC of 253° 52'. ANY DEFORMATION OF THE SPHERICAL SURFACE MUST FALL WITHIN THE ±.003 DIAMETRICAL TOLERANCE.

10. DIMENSIONS APPLY TO BOTH ENDS.

FIG. 6 LEAD, EXPLOSIVE, FLEXIBLE MK 11 MOD 0 ASSEMBLY

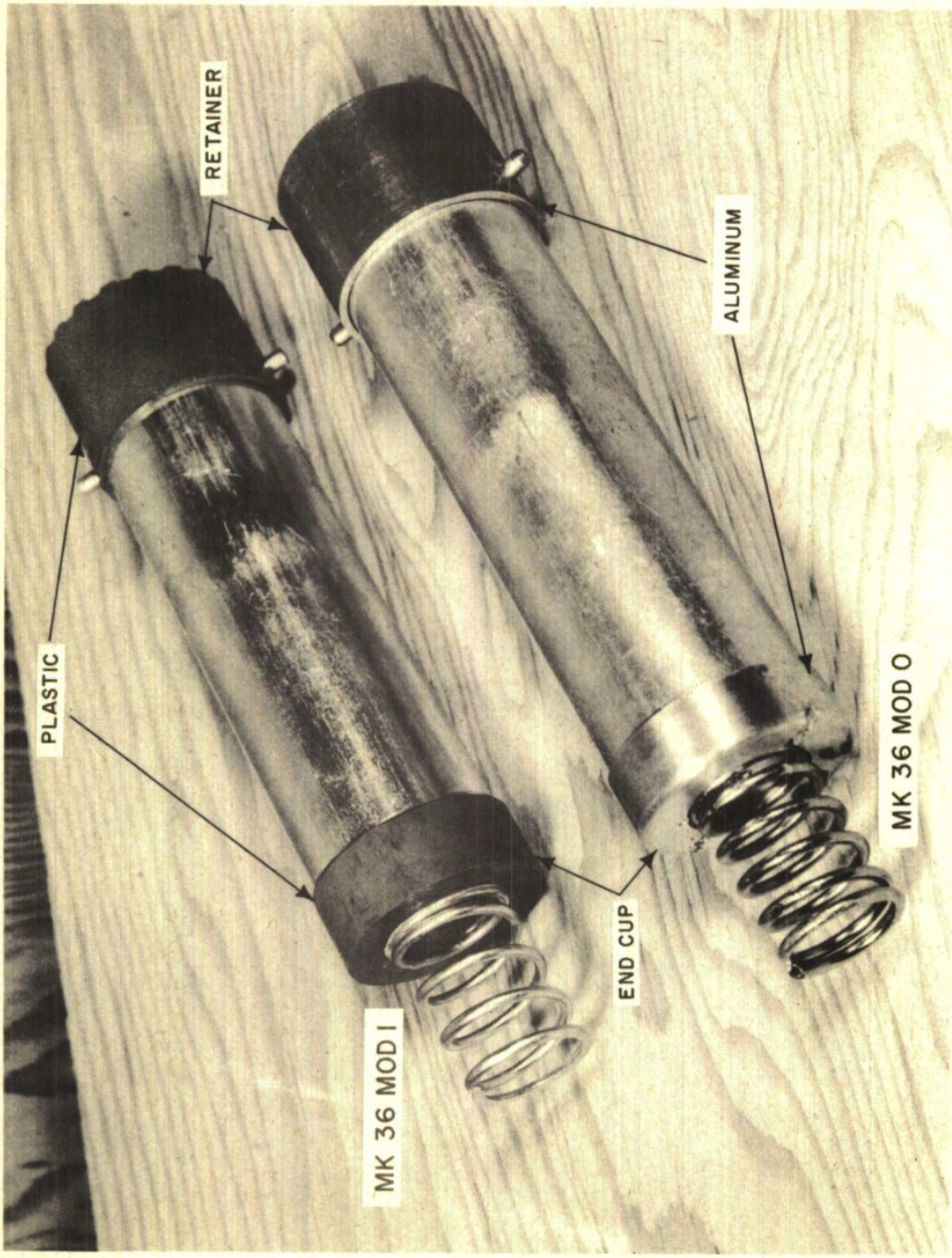


FIG. 7 WARHEAD BOOSTERS, MK 36 MOD O, AND MK 36 MOD I

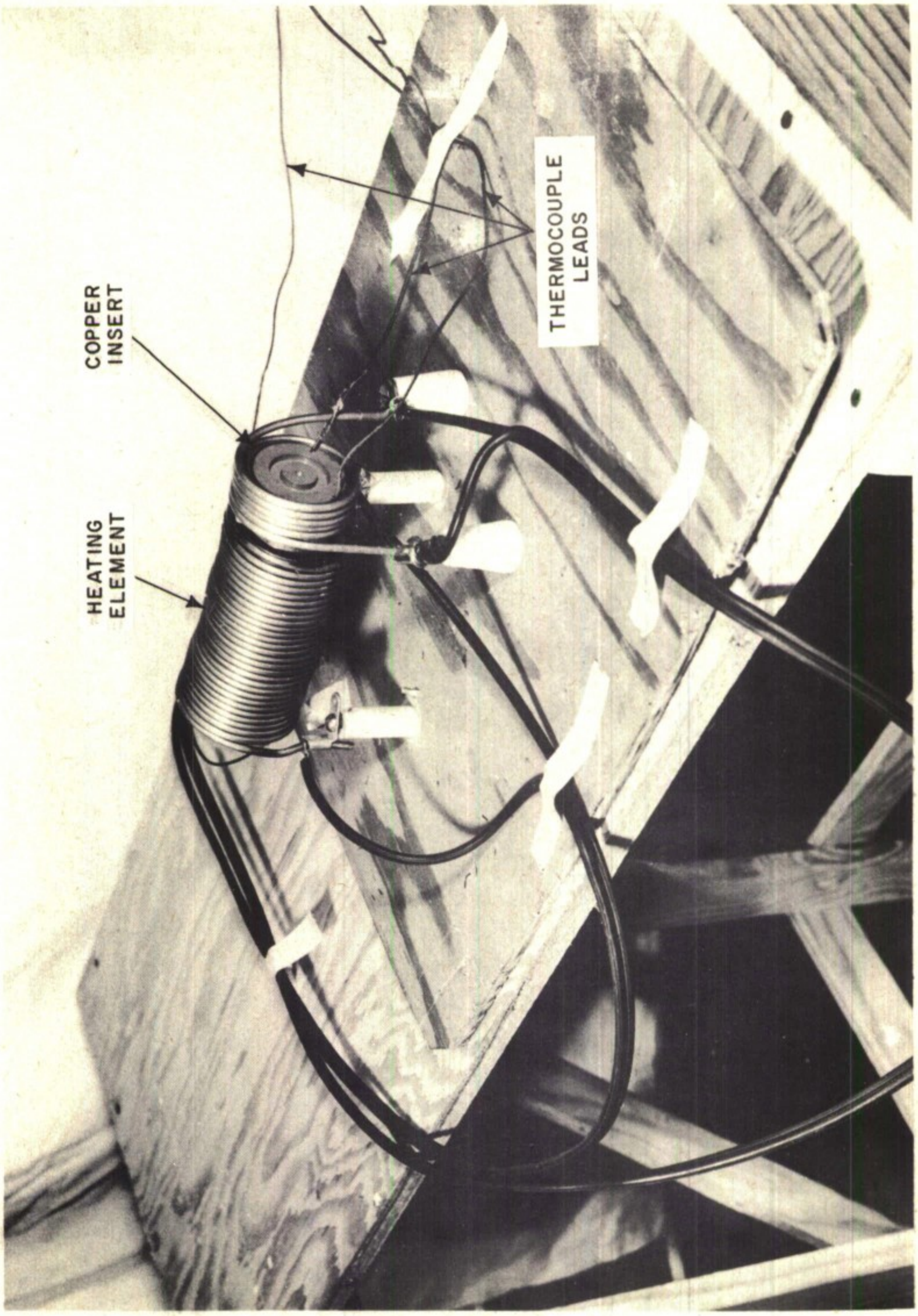


FIG. 8 HEATING ELEMENT TO TEST THERMAL CHARACTERISTICS OF WARHEAD BOOSTER MK 36 MOD I MINUS COMPRESSION SPRING

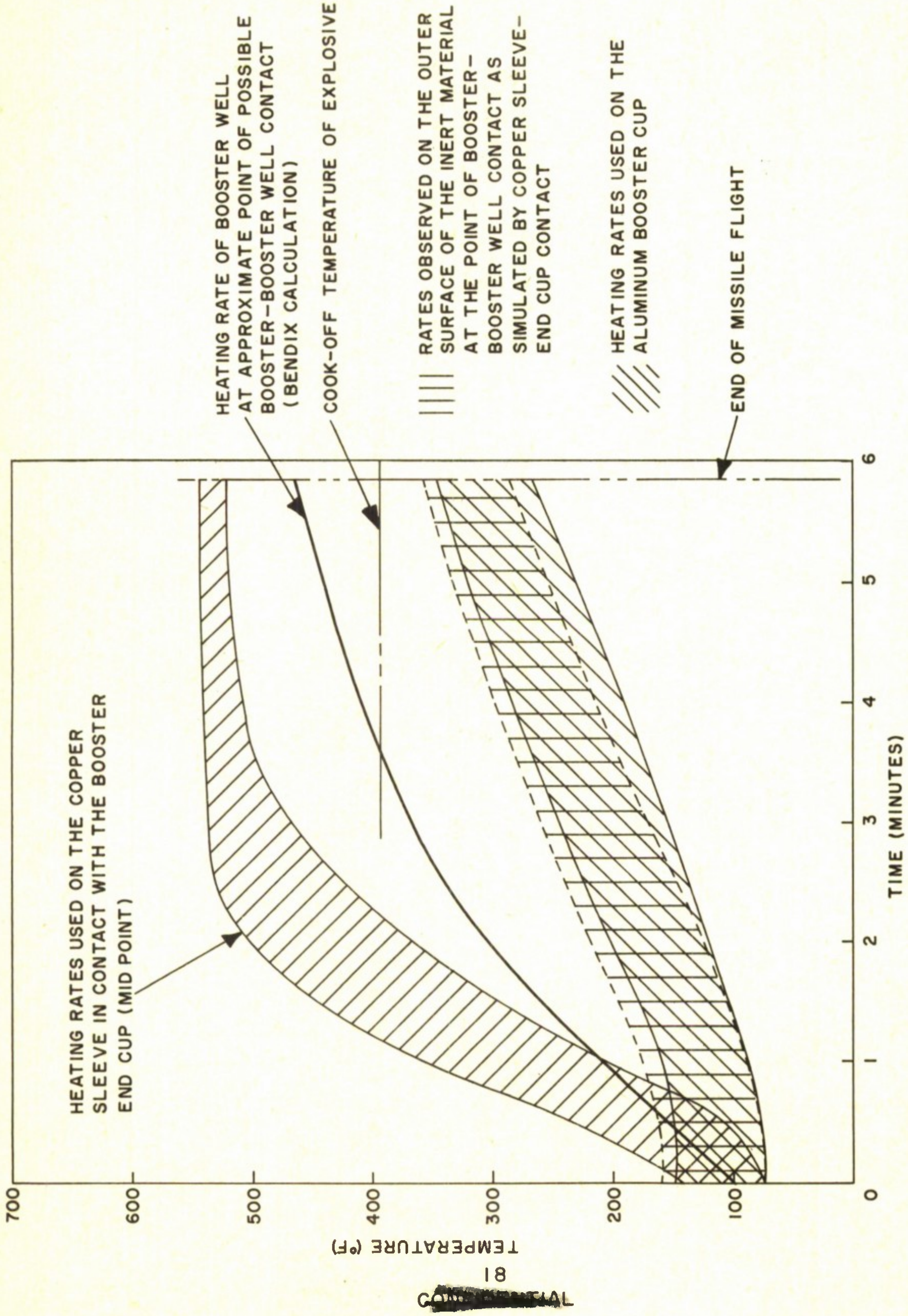


FIG. 9 THERMAL ANALYSIS OF INERT-LOADED WARHEAD BOOSTER, MK 36 MOD I

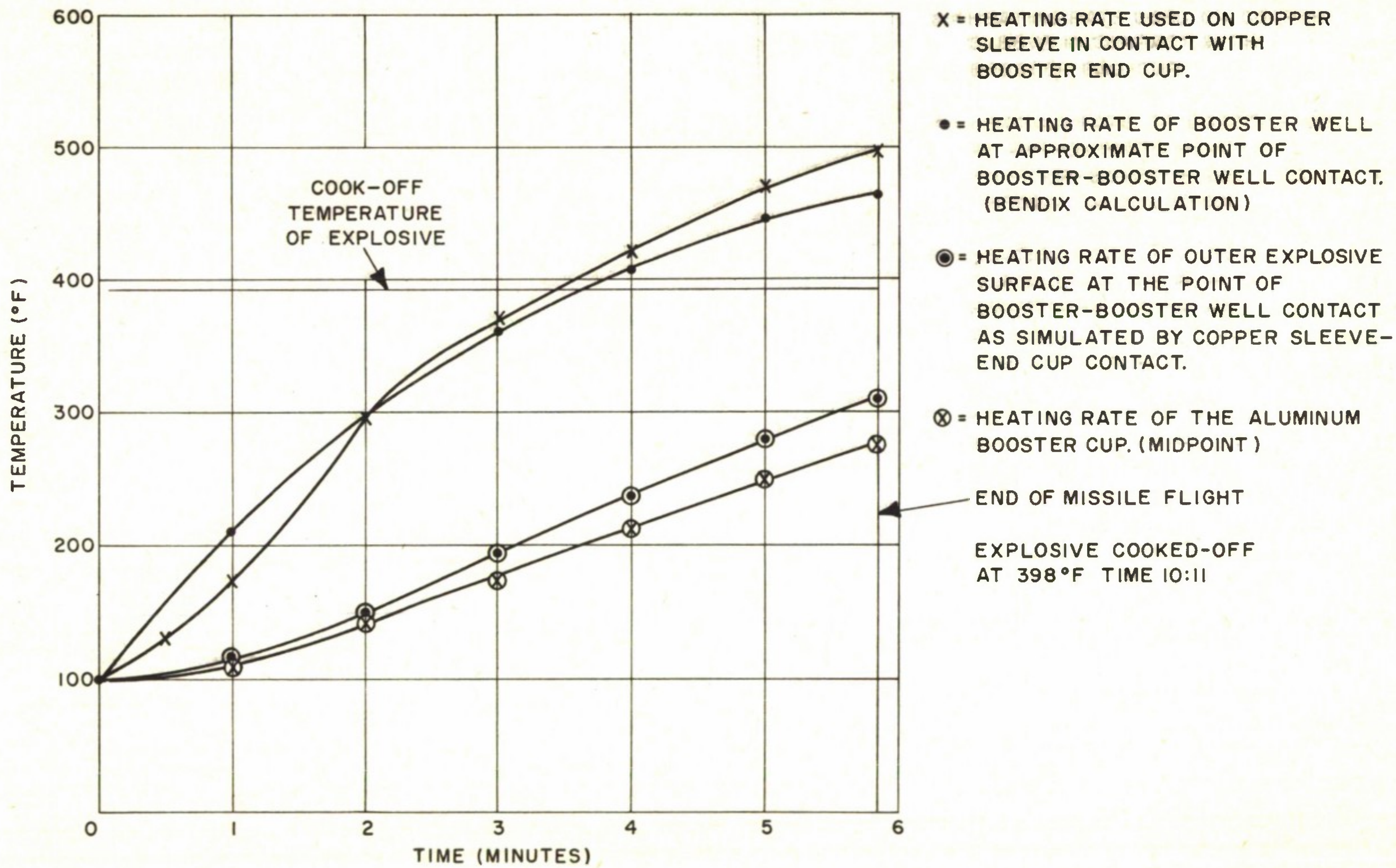


FIG. 10 THERMAL ANALYSIS OF LIVE-LOADED WARHEAD BOOSTER, MK 36 MOD 1 (RUN 1)

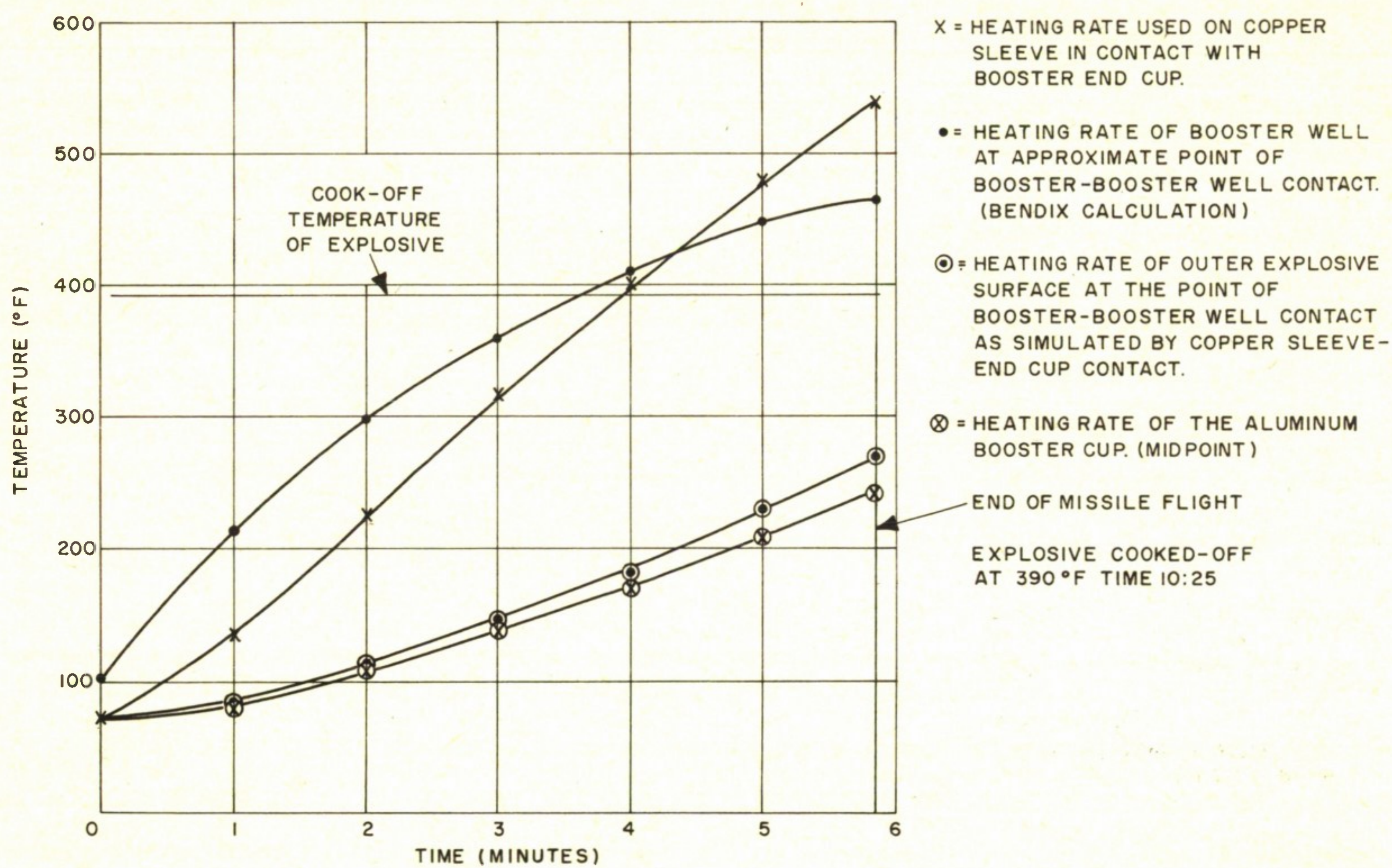


FIG. 11 THERMAL ANALYSIS OF LIVE-LOADED WARHEAD BOOSTER, MK 36 MOD 1 (RUN 2)

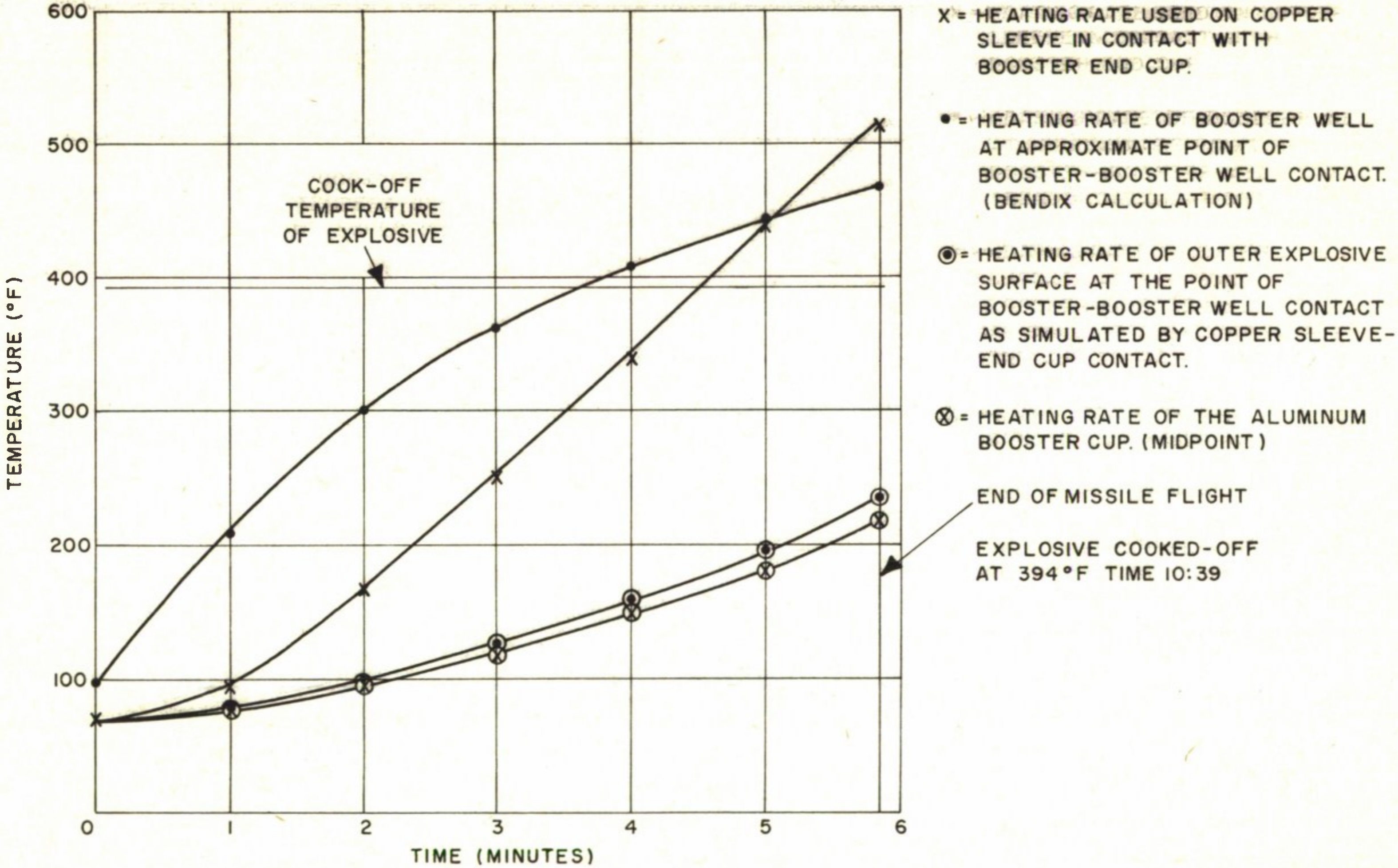


FIG. 12 THERMAL ANALYSIS OF LIVE-LOADED WARHEAD BOOSTER, MK 36 MOD I (RUN 3)

NOTES:

1. INTERPRET DIMENSIONS AND TOLERANCES IN ACCORDANCE WITH MIL-STD-8.
2. INTERPRET ABBREVIATIONS IN ACCORDANCE WITH MIL-STD-12.
3. FOR LIST OF DRAWINGS, ASSEMBLIES, PARTS, SPECIFICATIONS, ETC., SEE LD480229.
4. FOR OUTLINE DRAWINGS, SEE 1664570.
5. APPLY ADHESIVE RUBBER, MIL-A-5092 TYPE II, TO INNER PERIPHERY OF 1664573 AND 1664572 AND INSERT IN POSITION ON 1664571.
6. FOR DESCRIPTIONS, REQUIREMENTS AND PACKAGING, SEE OS 7299.
7. PINS 1619209, AFTER ASSEMBLY MUST BE $180^{\circ}00' \pm 1^{\circ}00'$ APART AND PERPENDICULAR TO $\boxed{\text{-A-}}$ .005.
8. FOR METHOD OF MARKING, SEE NAVORD OSTD 2.

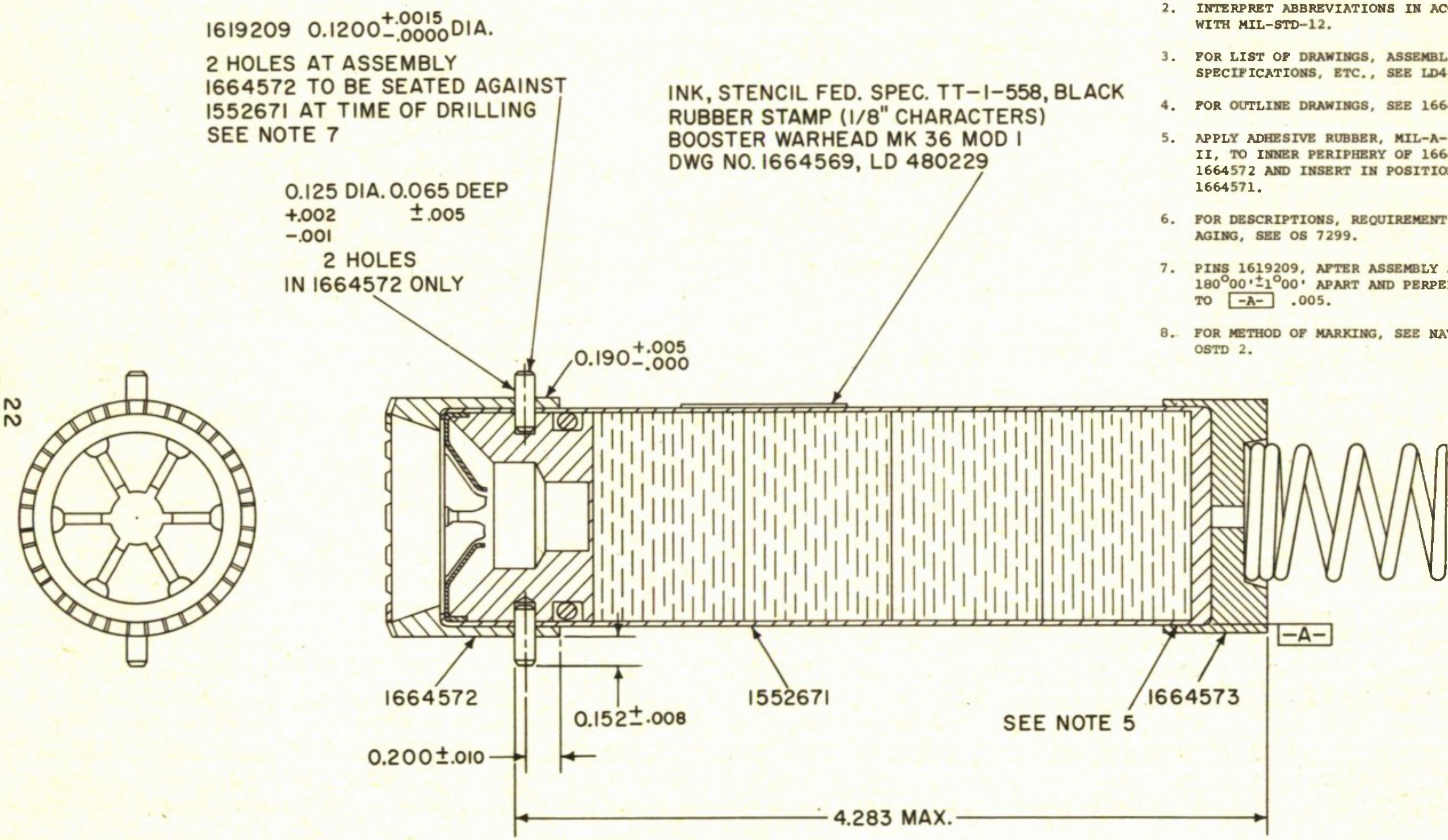


FIG. 13 BOOSTER, WARHEAD, MK 36, MOD I ASSEMBLY

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Armed Services Technical Information Agency Arlington Hall Station Arlington, Virginia TIPDR	10
Bulova Research & Development Inc. 62-10 Woodside Avenue (NOrd 11544) Woodside 77, New York	1
Bendix Aviation Corp. Bendix Products Division 400 South Beiger Street Mishawaka, Indiana (NOrd 18373)	1